REAL-TIME ELECTRICITY PRICING WITH HETEROGENEOUS CONSUMERS: WELFARE AND DISTRIBUTIONAL EFFECTS UNDER VARIABLE RENEWABLE ENERGY SUPPLY

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Overview

Giving consumers an incentive to consume less electricity when it is relatively expensive and more when it is relatively cheap can augment short and long run efficiency of real electricity markets (Borenstein and Holland 2005). While most electricity consumers still face time-invariant retail prices even though wholesale electricity prices vary by the hour, price responsive electricity demand is increasingly regarded as one of the most efficient options to accommodate increasingly volatile energy supply in systems where variable renewable energy sources (vRES) diffuse at high rates (Mills and Wiser 2014; Connect Energy 2015). Apparently, the allocative efficiency gains from raising the share of real-time priced consumers can be shown to increase substantially in markets with high shares of variable renewables (Gambardella et al. forthcoming).

Yet, while the efficiency argument for real-time pricing (RTP) appears intuitive when assuming a *homogeneous type of electricity consumer*, it is not so clear whether a sufficiently large fraction of customers with indeed quite *heterogeneous demand patterns* would actually accept to be put on RTP. More specifically, introducing RTP on a large scale may be opposed by many consumers who benefit from cross-subsidized energy consumption by fellow consumers, for instance (Borenstein 2007a). Hence, if a consumer consumes most of her electricity during hours of high energy prices, the more likely she will benefit from a flat electricity tariff, where less "peaky" consumers bear some of the consumption costs by consuming relatively little during high price hours and the other way round. Thus, introducing RTP could entail a large amount of redistributed consumption costs if consumers do not intend to adapt their behaviour. Amongst other things, these *perceived losses* from redistributed consumption costs among heterogeneous electricity consumers could pose a significant social acceptance barrier to the widespread introduction of RTP in a market. At the same time, allocative gains from RTP are theoretically highest if those customers switched to being real-time priced who would lose the most, that is, consumers who consume (too) much during high price hours and (too) little during low price hours. Consequently, this creates a "tension" between the efficiency implications and distributional impacts of introducing RTP across heterogeneous consumers segments.

Therefore, the first question our work is dealing with is as to what extent the amount of redistributed consumption costs changes in a market with higher vRES supply shares and whether this issue becomes more or less of a problem. Debates on whom to put on RTP often circle around the question whether to focus on large, usually industrial consumers, where costs of installing smart-metering infrastructure are relatively low compared to the potential benefits, or to enable also smaller customers from the residential or trades and services (T&S) sector. As these three consumer groups usually have heterogeneous consumption patterns, we will also take on this comparison. The second question is then as to whether and how much welfare gains might be left on the table, if the focus is put solely on large industrial consumers to achieve a certain portion of responsive or real-time priced demand.

Method

We conduct comparative statics regarding the gross welfare gains from increasing shares of RTP consumers in different customer groups and for varying shares of vRES. Doing so, we use a partial long-run equilibrium model of a perfectly competitive electricity market where all investments in generation capacity and decisions upon plant operation as well as consumption occur under perfect foresight. Investments in vRES are solely driven by a given tax on carbon emissions. The most crucial model feature is that a given share of consumers is able to receive and react to prices in real-time while the majority simply faces a flat electricity price, just as in real markets. The flat and real-time electricity prices (RTP) are determined in the retail sector, where homogenous retailers engage in Bertrand competition when buying electricity from generators and selling it on to the final customers. Analytically, this framework builds largely upon the approach by Borenstein and Holland (2005). Our main contribution is that we account for heterogeneous consumption patterns of differing consumer groups. In particular, we group consumers into residential, industrial as well as trades and services (T&S) customers and compute group-specific time series of hourly electricity consumption for the year 2013 using standard load profiles as used by German transmission system operators. These profiles are scaled up to fit both German total hourly load data as measured by ENTSO-e and sector-specific, final electricity consumption in Germany for 2013 as measured by Eurostat. Finally, to model group-specific electricity demand from flat and RTP consumers we apply an isoleastic demand function where the empirical consumption data serve as anchor points. Moreover, we compute hourly capacity factors for vRES capacity from 2013 infeed data for wind and solar power installations in the German grid. The numerical model is formulated as a non-linear mixed complementary optimization problem (MCP) using the software package GAMS.

Preliminary Results

So far, our analyses deliver two basic results*; first*, the redistribution of consumption costs from introducing RTP across consumer segments could become less of a problem with higher energy supply share from vRES. That is, the estimated total annual amount redistributed among the three consumer sectors shrinks from about €800 million in a market without vRES supply to about €114 million in market with roughly 65% of electricity supply coming from wind and solar power. This drop in redistribution can be explained by a drop in the correlation between electricity prices and private consumption of all consumer groups as soon as energy supply becomes more volatile with higher vRES supply shares. This is particular true for the residential and T&S consumers whose consumption co-varies a lot with prices at low vRES shares while industrial consumers have a rather flat consumption pattern anyways.

Secondly, we find that relatively large amounts of gross welfare gains from increasing the overall RTP share could be left on the table if only some of the large, industrial consumers would face real-time prices. More specifically, total annual welfare gains from putting either residential or T&S consumers on RTP to reach a given, aggregate RTP share of 10-20% are approximately 20-30% higher on average than putting only industrial customers on RTP to achieve this. This is simply due to the "peakier" demand pattern of residential and T&S customers. That is, the more a customer's electricity consumption varies over a day or between seasons, the more efficient it is to expose this customer to real-time scarcity of electricity supply and vice versa. This true for a market with and without high shares of vRES energy supply, however, in the former case we find that allocative gains from RTP could be as much as 30% higher on average.

Conclusions

This work analyzes the tension between the social acceptance of real-time retail pricing and its potential social benefits in a market with increasingly volatile energy supply due to the expansion of wind and solar capacity as observed in many markets. One of the main barriers to accept introducing RTP is the redistribution of consumption costs since many (small) consumers usually profit from cross-subsidized energy consumption. This is particularly true for consumers with a "peaky" demand profile, that is, for consumers who usually consume much when prices are high and little when prices are low. In this regard, our preliminary findings suggest that introducing RTP in a market with relatively high shares of volatile energy supply from vRES could become socially more acceptable as the redistribution of consumption costs becomes much less severe.

On the other hand, we find that implementing RTP should not only occur in the industrial sector, where consumers usually have a "flatter" demand profile, but across all customer segments. The reason is that overall efficiency gains from given increases in RTP are particularly high when "peaky" consuming customers in the residential as well as T&S sector switch from being flat to being real-time priced. With rising supply from variable renewables such as wind or solar power, these welfare gains become even higher, implying that it becomes increasingly important and efficient to incentivize customers from these groups. This is particularly true in light of the mandatory roll-out of smart-meters, which European regulators have agreed upon.

References

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